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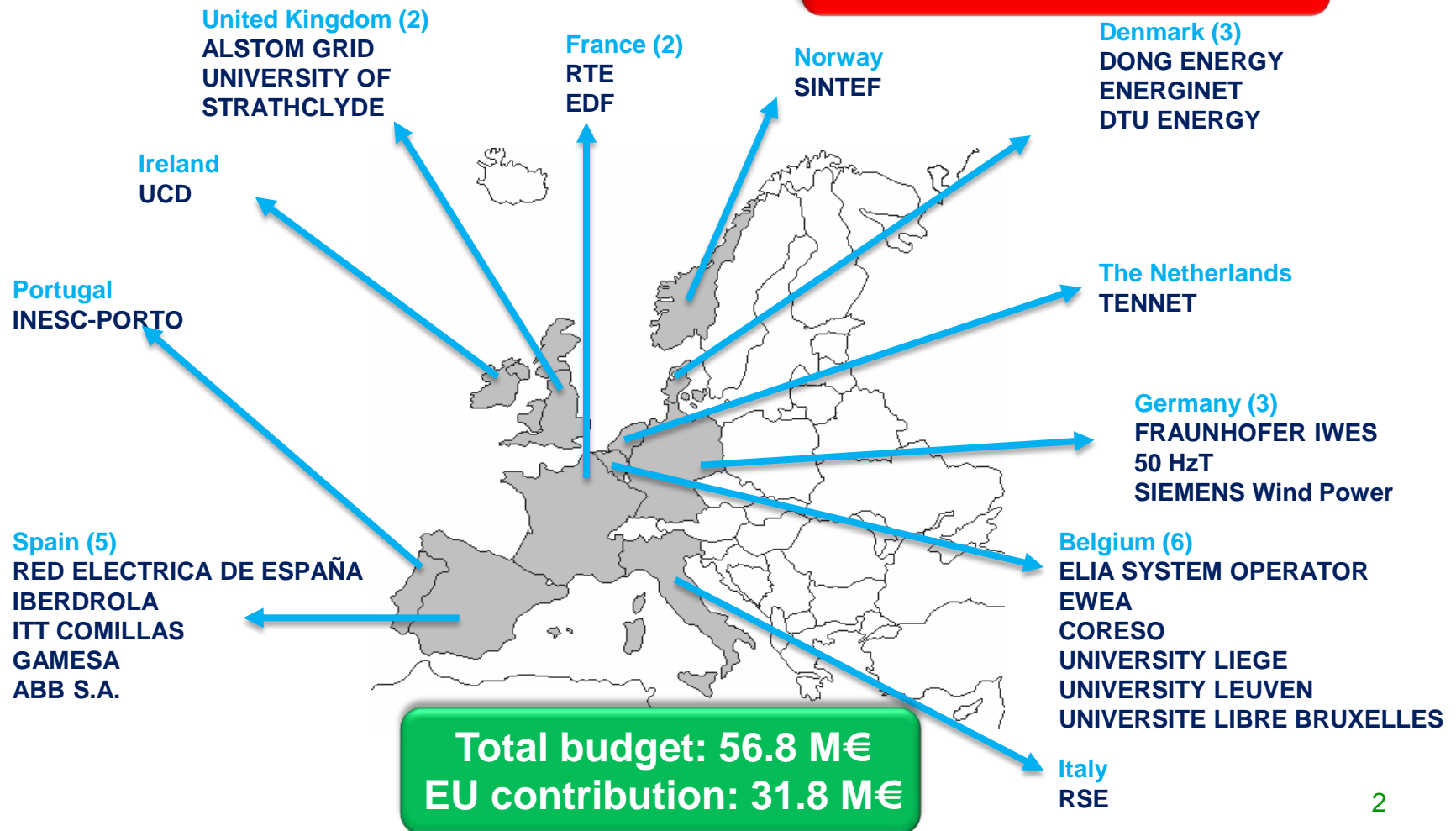
Wind power variability and power system reserve requirements at 2020 at 2030 scenarios for offshore wind power in Northern Europe

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Department of Wind Energy



Consortium and budget

**10 European Member States
1 Associated Country**



Project objectives

Task force 1: What are the valuable contributions that intermittent generation and flexible load can bring to system services?

Task force 2: What should the network operators implement to allow for off-shore wind development?

Task force 3: How to give more flexibility to the transmission grid?

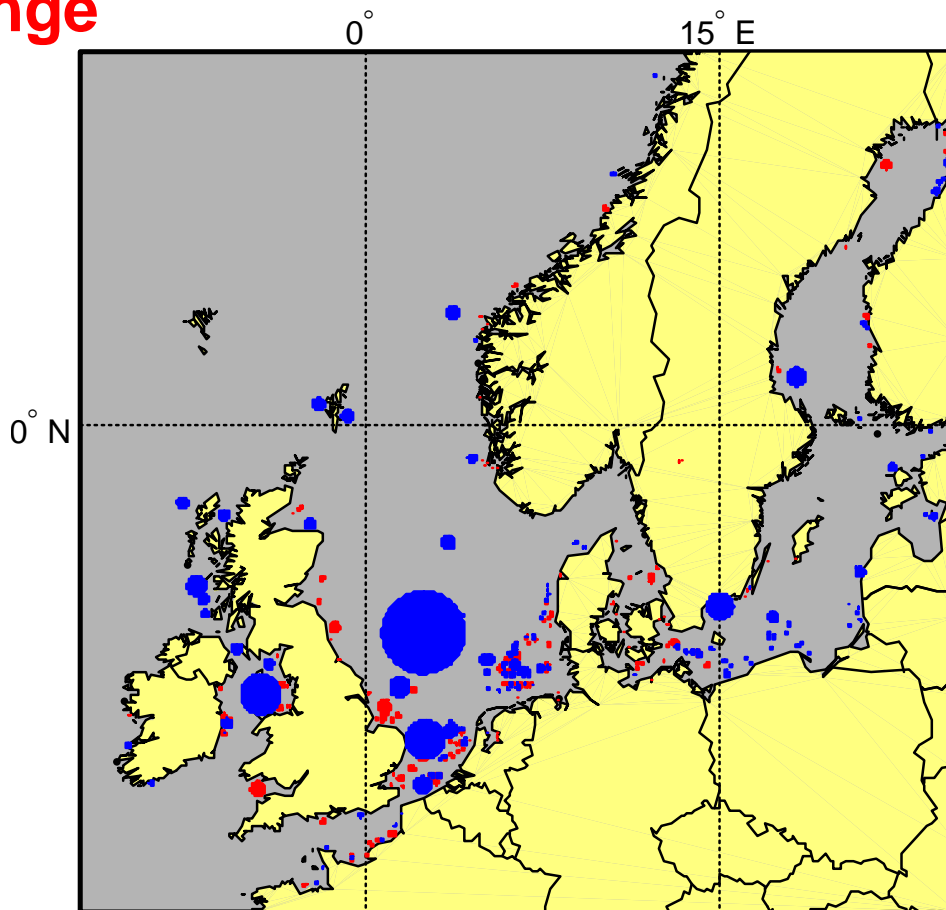
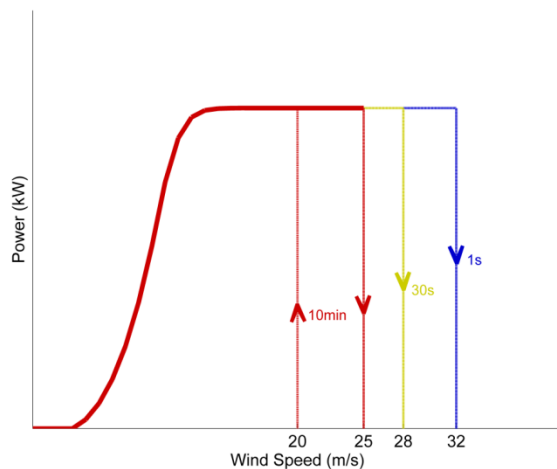
Overall: How scalable and replicable are the results within the entire pan-European electricity system?

**6 high level
demonstration
objectives**

**2 replication
objectives**

Demo 4 - The challenge

Power System Areas	2020 in MW		2030 in MW	
	Base	High	Base	High
UCTE	21,421	27,675	52,590	69,454
Nordel	4,924	7,019	15,009	20,512
UK+IR	15,130	21,500	37,920	52,090
Total	41,475	5,6194	105,519	142,056



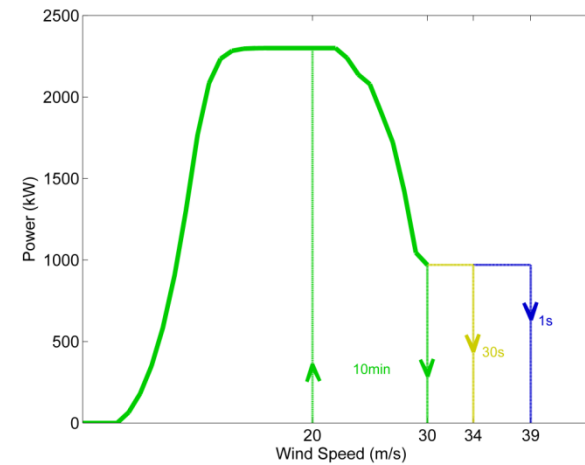
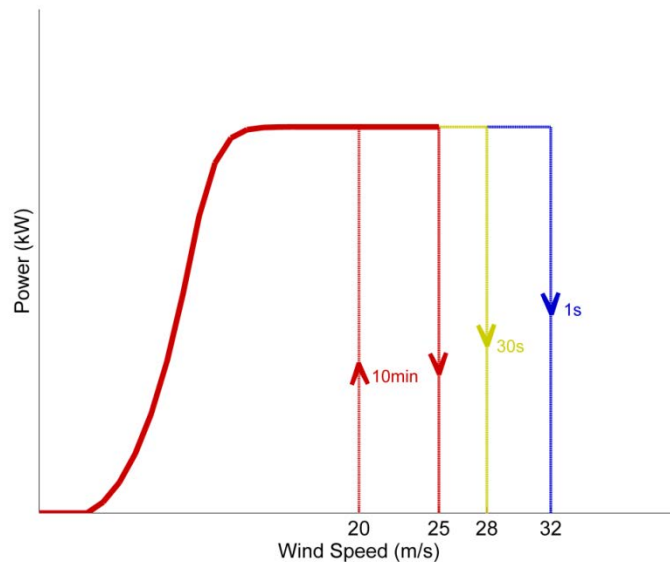
The demonstration

- Lead by Energinet.dk
- Horns Rev 2 wind farm owned by DONG Energy
- 91 x 2.3 MW Siemens wind turbines
- Siemens turbines built with conventional storm control
- Siemens developed and installed High Wind Ride Through™ - (HWRT)
- 3 years of storms monitored – including both controllers



Wind turbine modelling

- Conventional High Wind Shut Down (HVSD) wind turbine control
- Simplified model of Siemens High Wind Ride Through™ - (HWRT)



Storm events

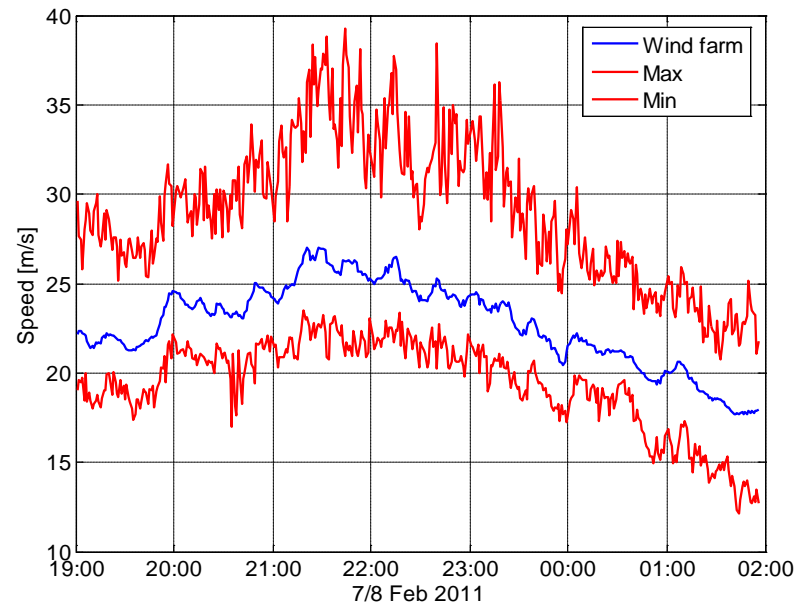
Event nr	Date	Controller
1	11-Nov-10	HWSD
2	12-Nov-10	HWSD
3	07-Feb-11	HWSD
4	24-Sep-12	HWRT
5	14-Dec-12	HWRT
6	30-Jan-13	HWRT

Legend:

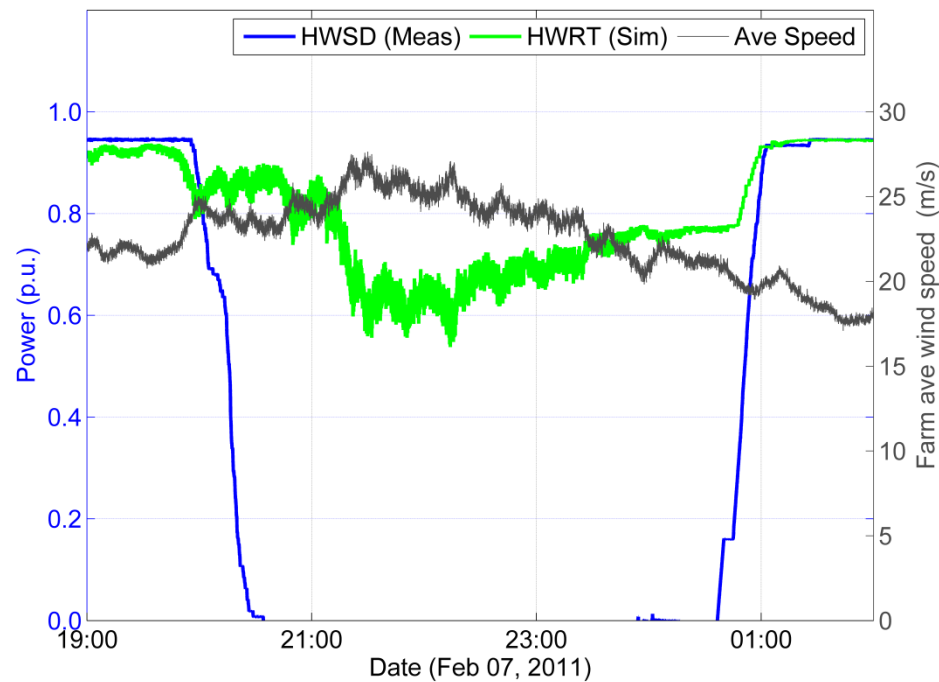
HWSD - High Wind Shut Down;

HWRT - High Wind Ride Through

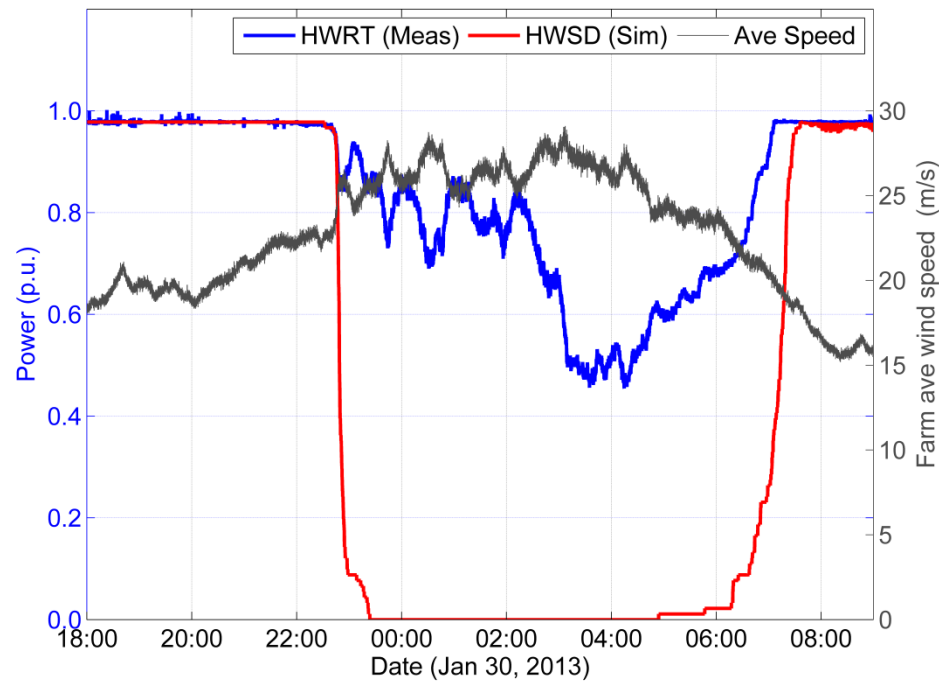
February 7-8 2011



February 7-8 2011

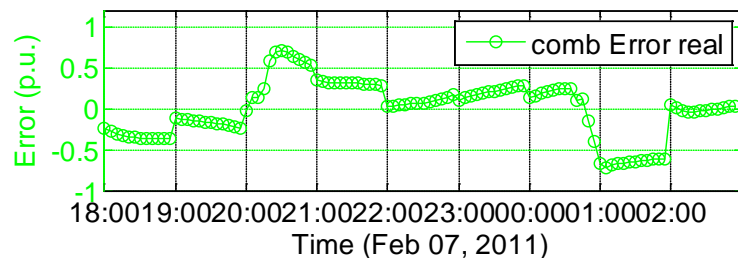
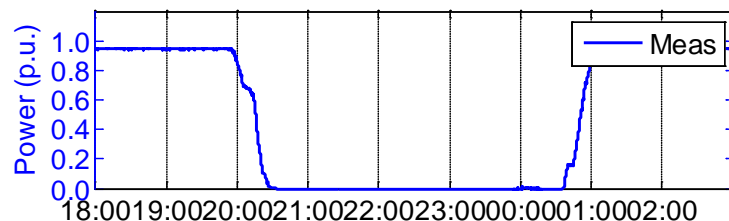


January 30, 2013

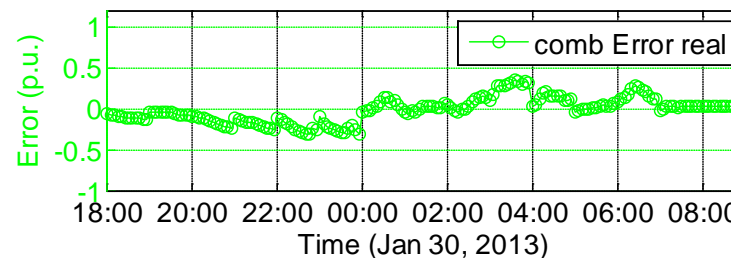
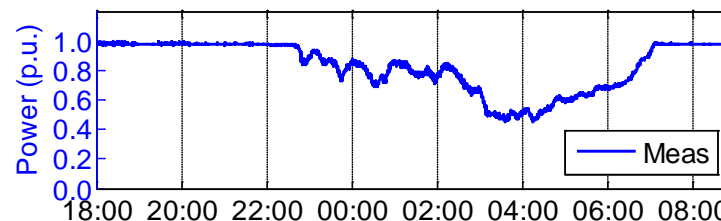


Wind turbine forecast error

February 7-8, 2011



January 30, 2013



Wind turbine forecast error

Event	Max forecast error [p.u.]	Average forecast error [p.u.]	Difference [p.u.]
11-Nov-10	0.80	0.77	0.51
12-Nov-10	0.80		
07-Feb-11	0.72		
24-Sep-12	0.26	0.26	
14-Dec-12	0.18		
30-Jan-13	0.35		

Replication work packages: barriers and up scaling

WP 15: Economic impacts of the demonstrations, barriers towards scaling up and solutions (Leader: IIT)

- Assess the **local economic and/or technological impact** of each demo.
- Identify the **barriers to scale-up** the outcomes at a member-state or regional level, and propose **solutions** to overcome these barriers.

WP 16: EU wide integrating assessment of demonstration replication potential (Leader: DTU Wind Energy)

- Assess **portability** of voltage control, frequency control and VPP model **to other countries and regions**.
- Evaluate North European 2020 **offshore wind power variability, hydro potential and barriers** and **grid restriction** studies.
- Pan European economic impact study.

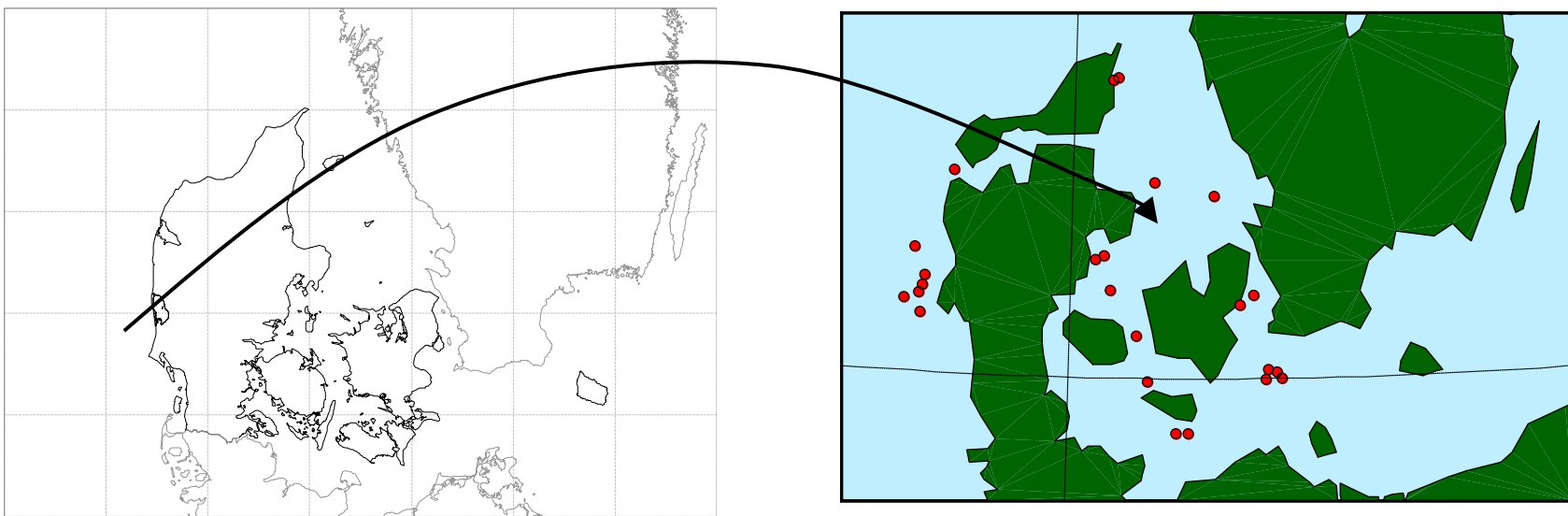
WP 17: EU Offshore barriers (Leader: TENNET)

- Address the issues of **smart licensing of submarine interconnectors** with and without wind parks in the North Sea and Baltic Sea.
- Identify **common licensing barriers** and propose regulatory measures.

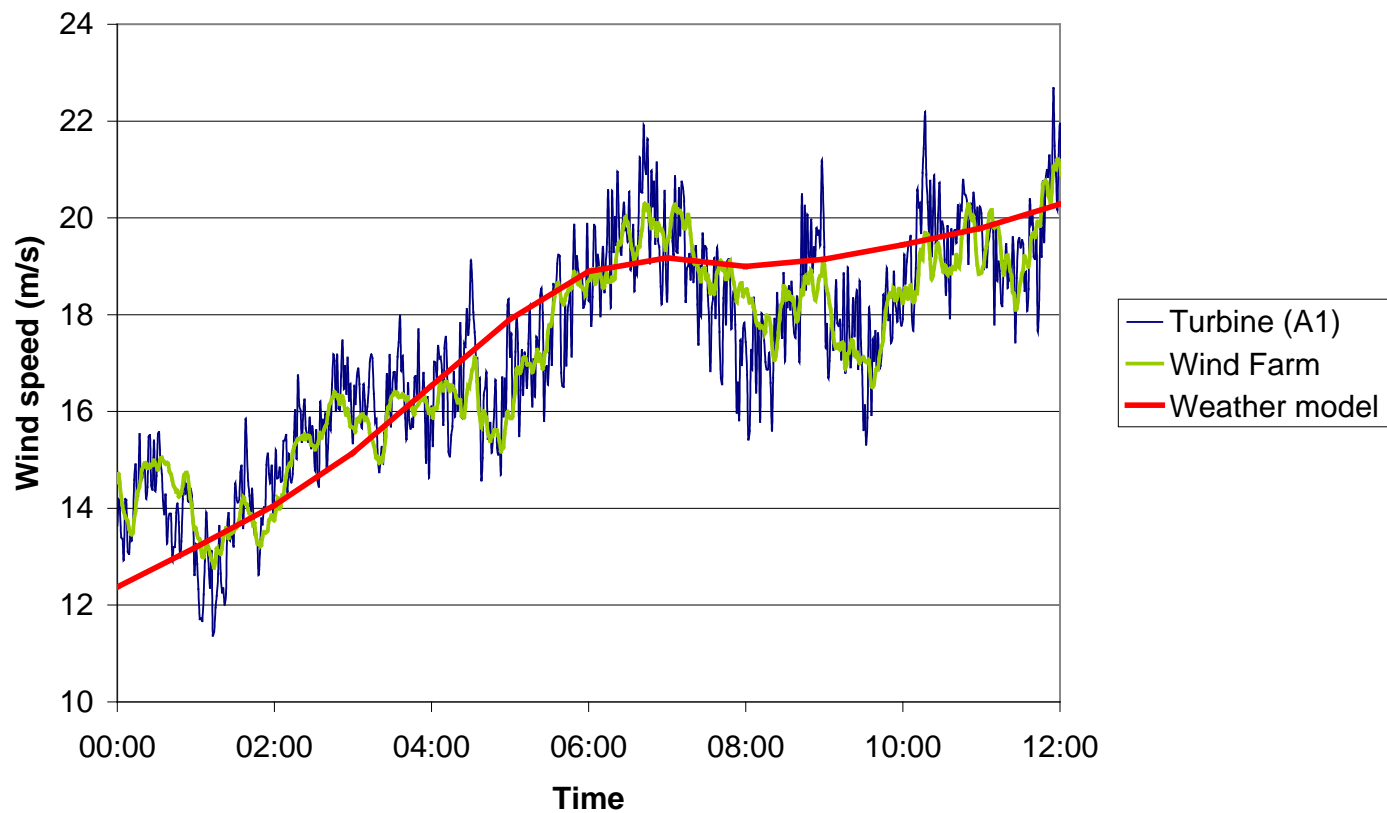
Upscaling of Horns Rev 2 to > 3 GW offshore wind

2020: 2.8 GW

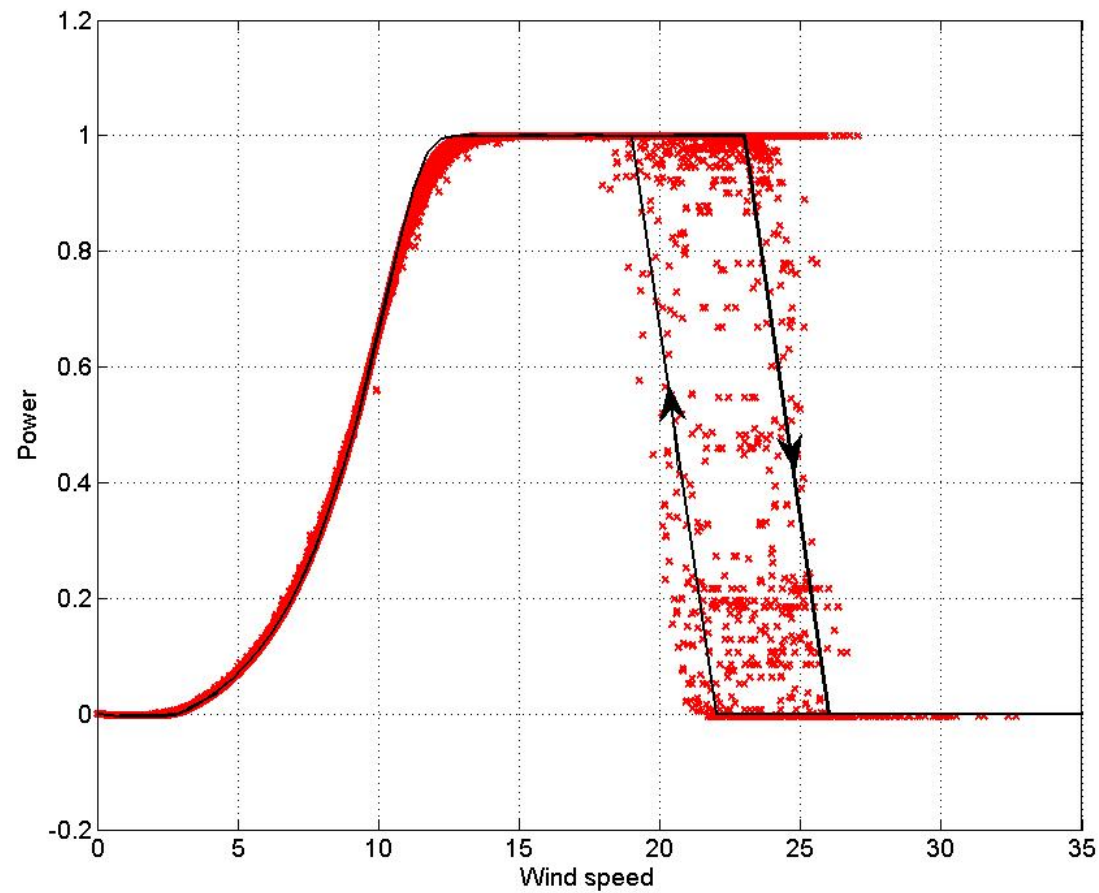
2030: 4.6 GW



Simulation of correlated wind power – CorWind



Aggregated wind farm model

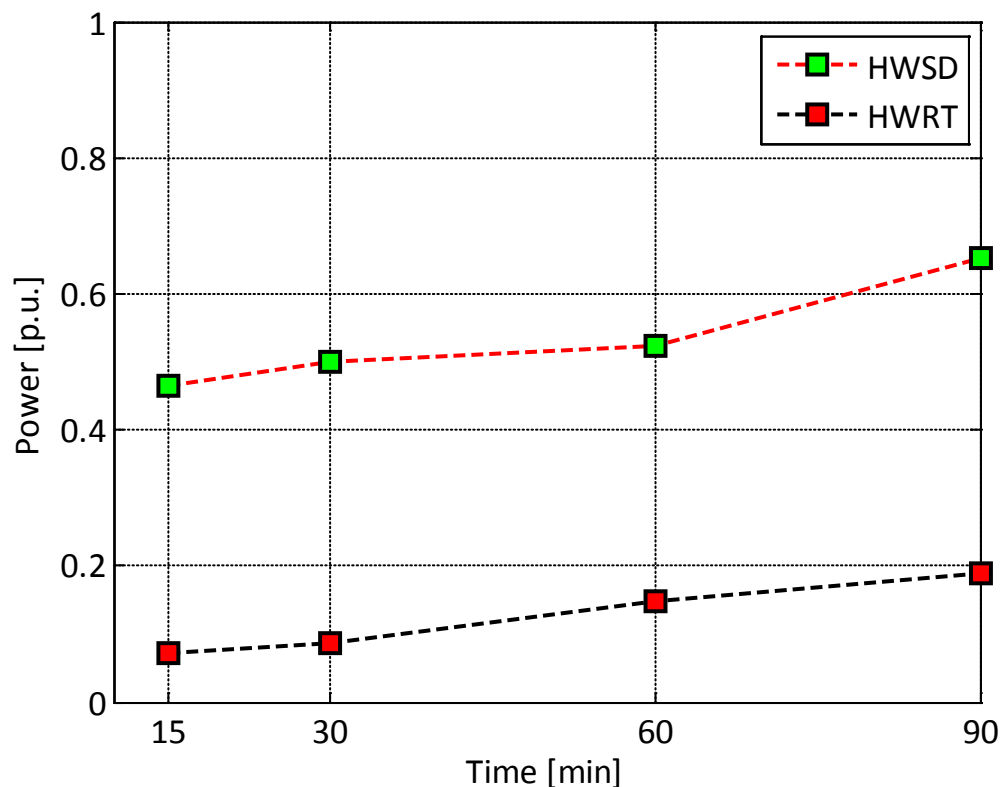


Critical weather periods

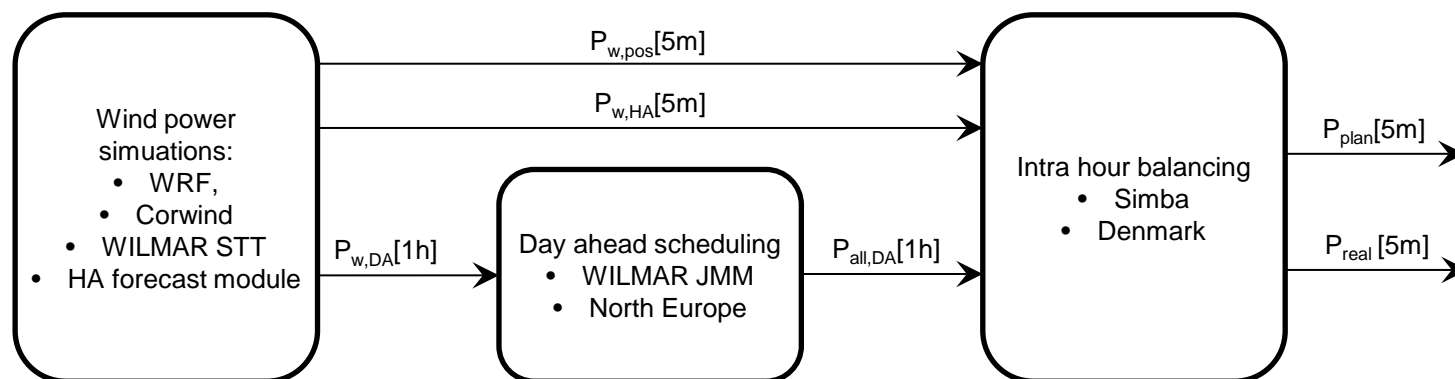
2001	01/01/2001	2008	21/03/2008
2005	02/01/2005		13/08/2008
2007	01/01/2007		08/11/2008
	08/01/2007	2009	11/06/2009
	18/03/2007		03/10/2009
	27/06/2007	2010	11/11/2010
	08/11/2007		07/02/2010
2008	25/01/2008	2011	10/03/2011
	27/02/2008		

Max ramping during storms – 2020

$$P_{\text{res}}(n) = P_{\text{mean}}[t(n) - T_{\text{ave}} ; t(n)] - P_{\text{min}}[t(n) ; t(n) + T_{\text{win}}]$$



Simba + WILMAR Intra hour balancing in storm events



Summary

- **Observations:**
 - Wind power forecast error reduced by 50% of installed capacity
- **Modelling:**
 - Maximum ramping in Denmark 2020 reduced more than three times

Thank you